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DESIGN AND STUDY OF LIGHT READOUT SYSTEM FOR SCINTILLATOR SHOWER MAXIMUM DETECTOR FOR THE ENDCAP ELECTROMAGNETIC CALORIMETER FOR THE STAR EXPERIMENT AT RHIC

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The possibility of using a strip/fiber-type shower maximum detector (SMD) in the endcap EMC for *pp*, *p*Au and AuAu collisions was investigated by simulation. It is shown that strip-type SMD is a good option for *pp* and *p*Au collisions, but is not suitable for AuAu. The compact module of 16 tiny Russian photomultipliers with one HV power supply channel is realized as a unit of a light readout system of the SMD.

The investigation has been perfomed at the Laboratory of High Energies, JINR.

Разработка и исследование системы светосбора сцинтилляционного детектора максимума ливня торцевого электромагнитного калориметра установки STAR на ускорителе RHIC

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Путем моделирования *pp*-, *p*Au- и AuAu-столкновений исследована возможность использования детектора максимума ливня стрипового типа в торцевом электромагнитном калориметре. Показано, что детектор максимума ливня стрипового типа может быть использован для pp- и *p*Au-столкновений, но не пригоден для AuAu-столкновений. Для светосбора с детектора максимума ливня разработан и создан компактный модуль, состоящий из 16 миниатюрных русских фотоумножителей с единым высоковольтным питанием.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

The investigation performed by the IHEP group indicates that scintillator strip/fiber-type shower maximum detector (SMD) [1] is a good option for the barrel electromagnetic calorimeter for the STAR experiment [2]. There [1] has been tested only one photoreceiver — Russian photomultiplier FEU85. We have continued investigations in this direction with the goal to find a new compact module type sheme of light readout based on low-current tiny Russian photomultipliers. In this case only one HV channel of a standard power supply source should be enough to feed one light receivers module.

We would like also to reply on the question whether it is possible or not to use a scintillator strip type endcap SMD not only in investigations of polarized proton collisions at RHIC but in study of *p*Au and AuAu collisions as well. For this purpose we have carried out Monte Carlo simulation.

The proposed endcap EMC is a lead-scintillator sampling calorimeter. The inner and outer edges of the endcap EMC subtend polar angles of $\Theta = 15.4°$ and $\Theta = 38.3°$, respectively, and it will cover the rapidity range from 1.0 to about 2.0. The space available for the endcap EMC and its electronics ranges from $Z = 2712$ to $Z = 3087$ mm, with Z along the beam direction, and covers radial range from $r = 774.8$ to $r = 2460$ mm, respectively.

It is proposed that the SMD will be placed into the endcap EMC at a depth of $5 \div 7X_0$ into 2.5 mm gap. It will consist of $\Delta\varphi = 30°$ sections each of which includes two sets of scintillator strips, placed perpendicularly each to another and oriented at 45° angle to the center line of the section. The light readout from each strip will be done by means of wavelength-shifting (WLS) fiber, mounted in a groove of the strip and connected by clear fiber (about 3m) to a photoreceiver (PMT or avalanche photodiode).

2. Monte Carlo Simulation

The Monte Carlo program GEANT 3.15 with a 1 MeV cut for γ's and electrons was used to study EM showers, and HIJING model event generator has been used to describe proton-nucleus and nucleus-nucleus collisions.

Figure 1 shows rapidity distribution of γ's and hadrons in *pp*, *p*Au and AuAu collisions at an energy of 200 GeV/nucleon. The distributions of energies of direct gammas and gammas from π^0 decays in acceptance of endcap EMC are presented, too. It is seen, that main background in SMD is related with π^0 channel of γ production. The number of γ's in the SMD acceptance is about 800 in central AuAu collision and about 10 in central *p*Au collision.

The γ-initiated showers are symmetrical with respect to the line of flight of the primary γ. In Fig.2 are shown transverse profiles of 15 GeV γ shower in the first and the second plane of SMD, placed into endcap EMC at the depth of $5X_0$'s about the position where the maximum development of shower occurs. To identify the single shower the scintillator strips must have the width not larger than 12 mm. The IHEP group data confirm our results [2]. We use 1 cm width scintillator strip in our investigations.

In Fig.3a are shown the charged particles multiplicity distribution on the first SMD plate for the central *p*Au and AuAu collisions. Referring to Fig.3b, where is presented the energy deposited in SMD scintillator vs. distance from the center of SMD, one can see that about 75% of the showers are in the central area 75 cm $< R <$ 160 cm. This area contains about 600 γ's (AuAu collision case). In Fig.4 is shown the energy deposited in the central 5 cm wide ring of SMD vs. azimuthal angle for 6°, 3° and 1°/ per bin. The one 3° bin contains ~3 strips and covers an area of about 40 cm. This area contains only one shower. It is seen that using 3° azimuthal bin the showers could be separated. The 75 cm $< R <$ 160 cm

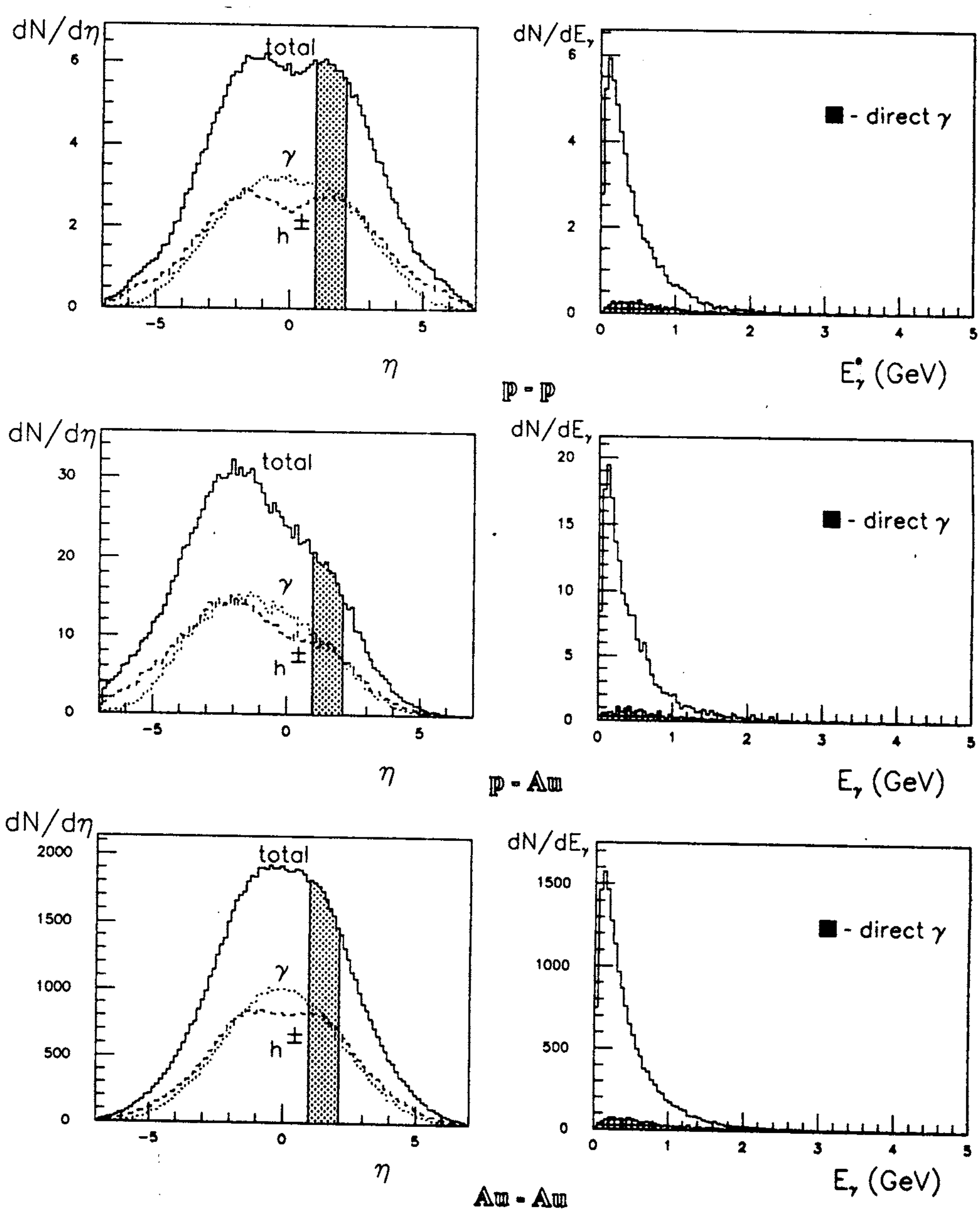
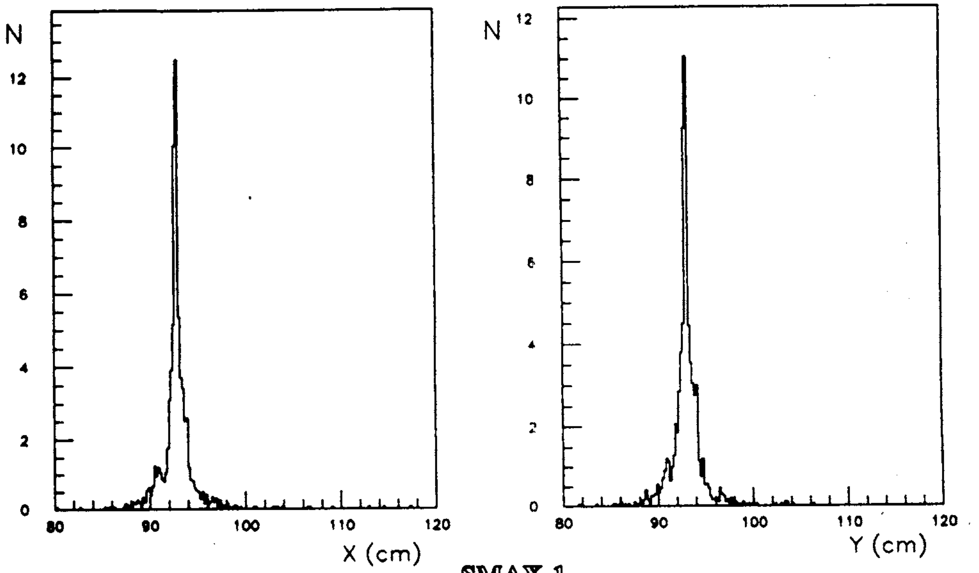
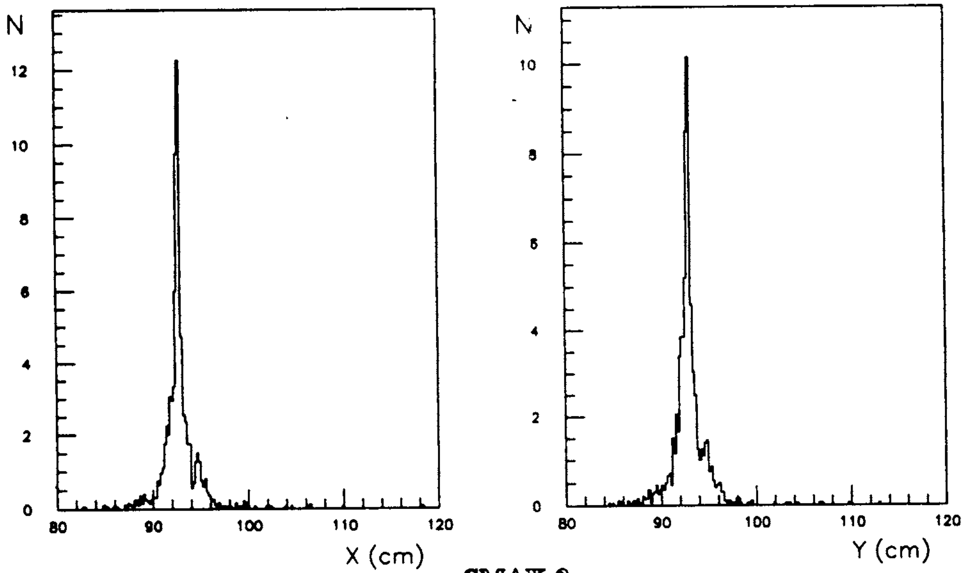


Fig.1. The pseudorapidity distribution of γ's and charged hadrons in *pp*, *p*Au and AuAu collisions at 200 GeV/nucleon

ring contains about 100 strips per 30° sector, so we have ~1.5 γ's per three strips. Then, we can conclude that the strip-type SMD is not suitable for separating the showers from AuAu collisions.



SMAX-1



SMAX-2

Fig.2. The transverse profiles of shower, induced by 15 GeV gamma

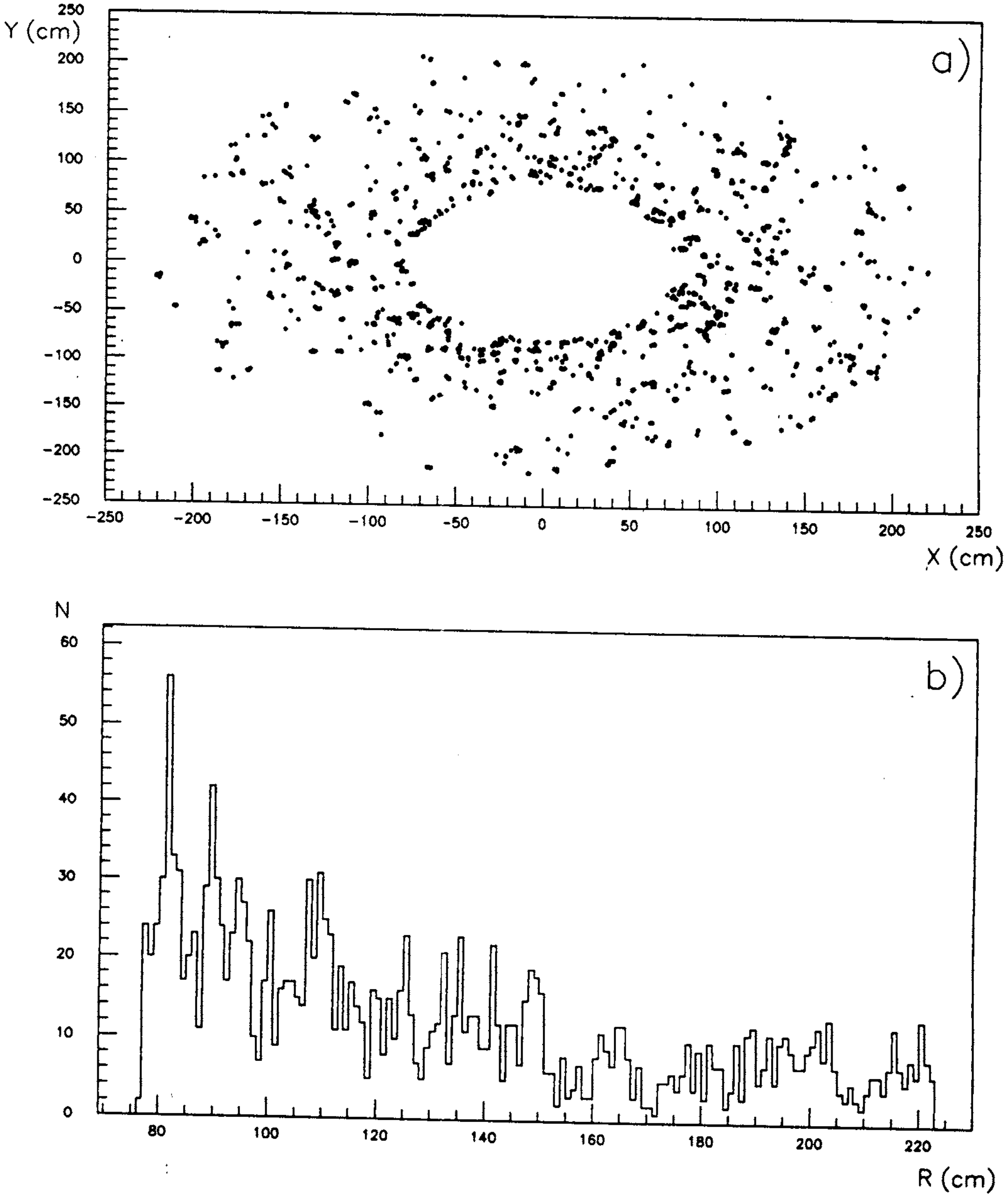


Fig.3. (a) Scatter plot of shower charged particles distribution on the first SMD layer; b) The number of shower charge particles vs. the distance from the SMD centre

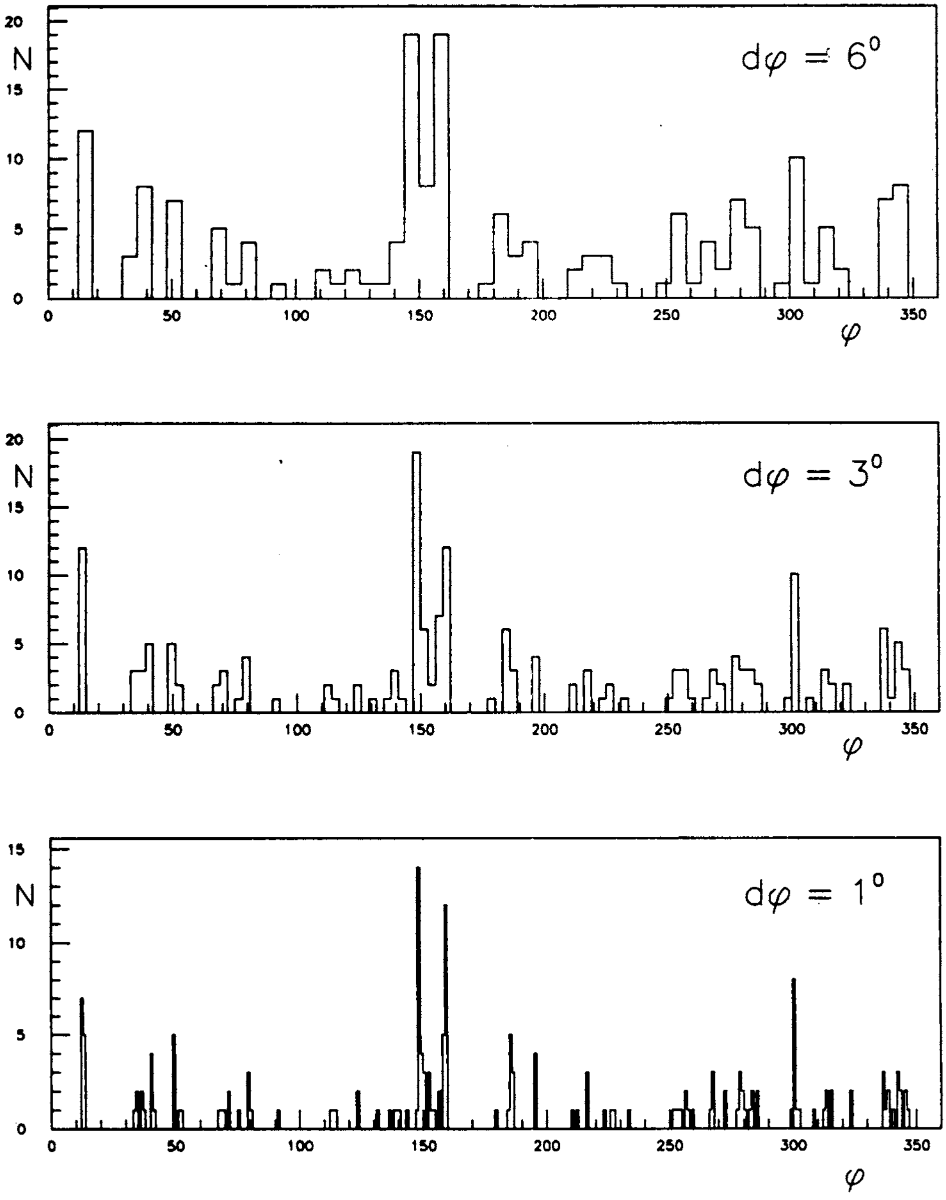


Fig.4. The energy deposited in the central 5 cm wide ring of SMD vs. azimuthal angle for 6°, 3° and 1° per bin for the central AuAu collisions

3. SMD Prototype Design

Following by results of our simulations and experimental study [2,3] the optimal thickness of scintillator strip is 4 ÷ 6 mm and its width is 10 ÷ 12 mm in order to obtain needed position resolution. We used a scintillator strip of 10 mm width and 4 mm thickness in our studies. In this case the full SMD will contain about 5300 strips. The SMD strips were read-out with wavelength-shifting fibers. The light collected by WLS fiber is transported via a long clear fiber to photodetector. The scintillator and the WLS fiber were wrapped with an aluminum foil. The hodoscope's scintillator plane of prototype contains 16 strips. Our investigations, the results of which are given in the next chapter, show that compact Russian photomultipliers like FEU-162, FEU-96 and FEU-60 with the gain more than 10^5 and quantum efficiency of photocathode about 15% can be used in SMD as photodetector. The high resistance dividers of the PMTs with about 100 μA current are used. The tested photomultiplier's specifications are given in Table 1. It allows us to use only one 2mA high voltage power supply channel for 16 phototubes module of the SMD and significantly reduce the cost of production of the HV power system. The two stage amplifier with the total gain about 10^3 is used for getting the suitable PMT pulse height. As an amplifier unit we used the Russian charge amplifier chip «Garantija» with the maximum gain about 10^2. The electronics components of the first amplifier cascade is placed just at the PMT divider board to reduce a noise. The photomultipliers operate at the nominal anode voltage ~1000V (FEU-60, FEU-68, FEU-85) and ~1500 V (FEU-96, FEU-162).

The prototype module of 16 photomultipliers has the size 12 × 12 × 30 cm. The total number of modules (324 units) for the hole SMD will have the size 216 × 216 × 30 cm. The prototype module is shown in Fig.5.

Table 1

Parameters	FEU-85	FEU-162	FEU-96	FEU-60	FEU-68
Diameter, mm	30	22.5	22.5	15	15
Length, mm	107	75.0	75.0	70	70
Photocatode type	Sb-Cs	Sb-Na-K-Cs	Sb-K-Sc	Sb-Cs	Sb-Na-K-Cs
Quantum efficiency ($\lambda = 480$ nm), %	10	15	15	10	15
Gain	$\sim10^6$	$\sim10^5$	$\sim10^5$	$\sim10^5$	$\sim10^4$
Current divider, μA	100	100	100	100	100

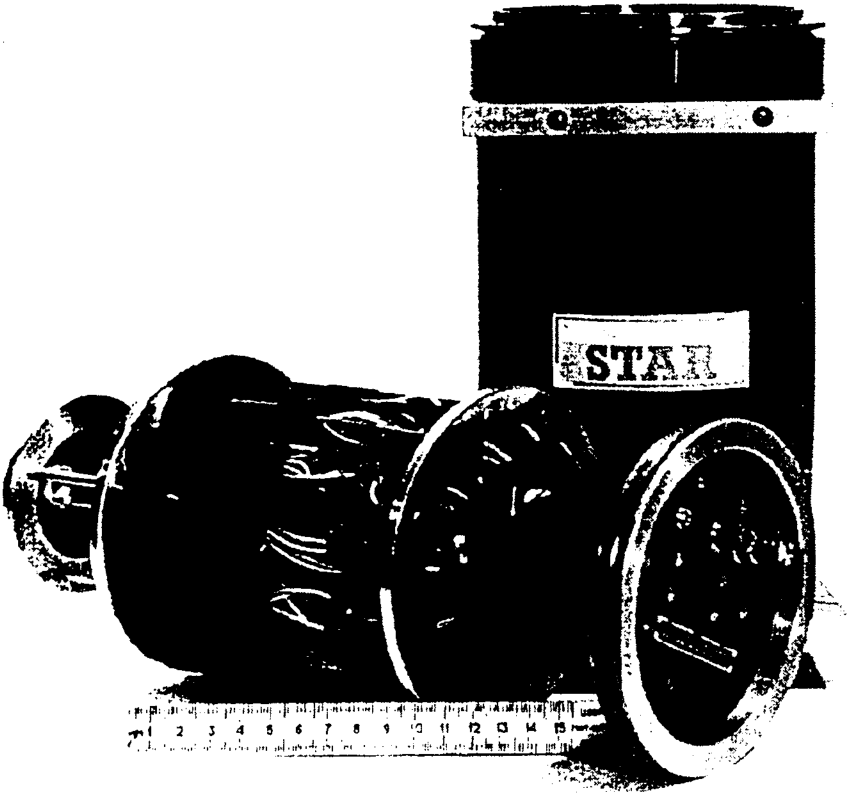


Fig.5. The phototype SMD module of 16 photomultiplier

4. The PMT Test Experimental Set-Up

A number of tests have been performed with Russian photomultiplier FEU-60, FEU-68, FEU-85 and FEU-162. Figure 6 shows a schematic view of the experimental set-up and logic of the measurements.

A WLS fiber BCF-91A with diameter of 1 mm, ($\lambda = 480$ mm) was used. A clean fiber BCF-91B had length ~1 m. The thickness and the width of the scintillation strip were 4 mm and 10 mm, respectively. Data were taken with Ce-144 source. The gate of ACD was ~60 ns and have been produced by coincidence of Monitoring Counter (FEU-87) and Coinciding Counter (FEU-87) signals. The threshold of Monitoring Counter was about 400 keV and defined the low level of scintillator light.

The Coinciding Counter threshold was as low as possible in order to detect all electrons passed through scintillator strip.

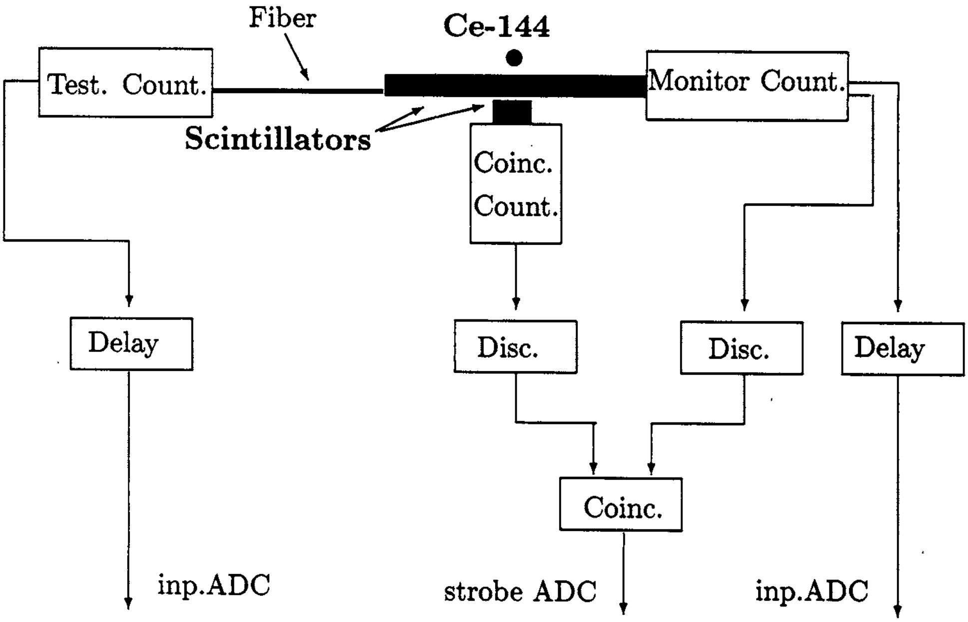


Fig.6. The experimental set-up and logic of the test measurements

The testing PMT were placed one by one in turn into Experimental Counter area so they have the equal optical conditions.

5. Results

At first, we have repeated the IHEP test of EU-85. Pulse heights measured with FEU-85 are shown in Fig.7. One can see that our results are in good agreement with IHEP data and we can conclude that our optical chain works right.

For PMT FEU-85, which has a gain of about 10^6, we obtain ~2.5 photoelectrons per MIP. Figures 8a, 8b and 8c show the results of test for FEU-162, FEU-96 and FEU-60, respectively. They have a gain of ~10^5. The total gain of read-out electronics was 120 (FEU-162), 80 (FEU-96) and 80 (FEU-60). In the case of PMT FEU-85 it was ~20. The ADC pulse heights distribution for FEU-68 is shown in Fig.8d.

The results of our PMT tests are summarized in Table 2.

One can see that the photomultipliers with gain more than 10^5 are suited for using as photoreceiver in SMD.

Table 2

PMT	PMT gain	read-out gain	$N_{p.e.}$/MIP
FEU-85	$\sim 10^6$	20	y2.5
FEU-162	$\sim 10^5$	120	~1
FEU-96	$\sim 10^5$	80	~1
FEU-60	$\sim 10^5$	80	~1
FEU-68	$\sim 10^4$	450	~0.7

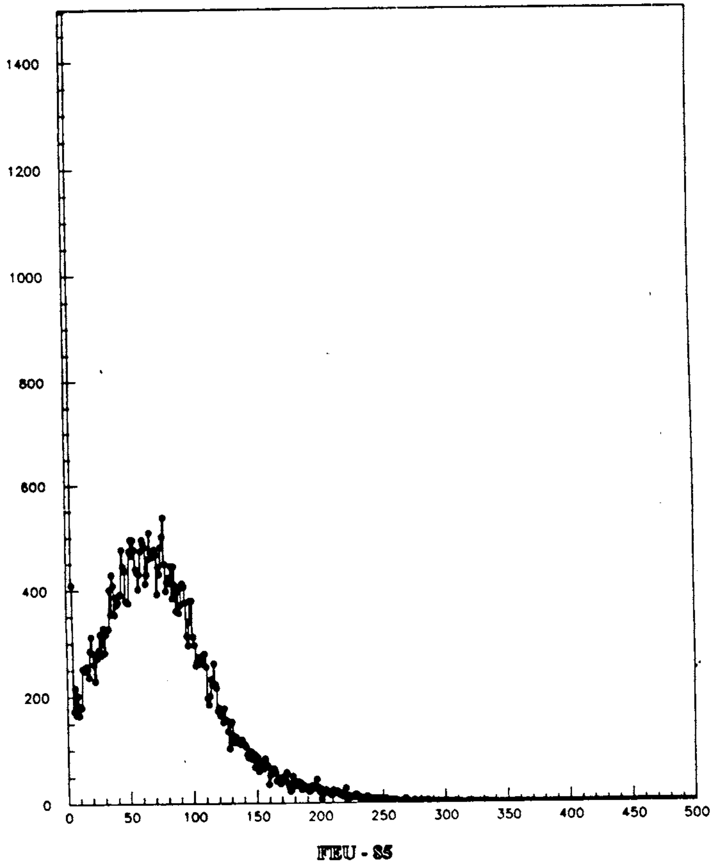


Fig.7. The ADC pulse heights distribution measured with FEU-85

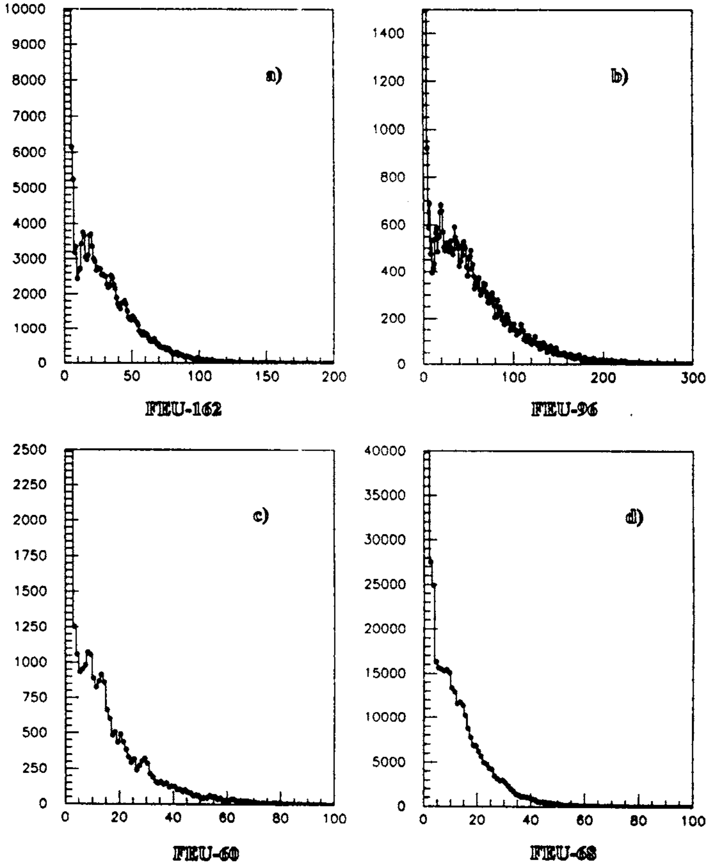


Fig.8. The same as in Fig.7 for the FEU-162, FEU-96, FEU-60 and FEU-68

6. Conclusions

The possibility of using a strip/fiber-type shower maximum detector (SMD) in the endcap EMC for the STAR experiment at RHIC for *pp*, *p*Au and AuAu collisions was investigate by simulation. It is shown that strip-type SMD is a good option for *pp* and *p*Au collisions, but is not suitable for AuAu. The compact $12 \times 12 \times 30$ cm module of 16 tiny Russian photomultipliers with one HV power supply channel is realized as a unit of light readout system of the SMD.

7. Acknowledgements

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References

1. Akimenko S.A. et al. — IHEP Preprint 94-94, Serpukhov, 1994.
2. Conceptual Design Report for the Solenoidal Tracker at RHIC, the STAR collaboration, PUB-5347 (1992).
3. Solenoidal Detector Collaboration, Technical design Report. SDC-92-201, SSCL-SR-1215, 1 April 1992.

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